The Operational Limits of Emerging Technology

*by Dr Steven L. Canby**

In IDR 5/1985, Dr James A. Tegnelia presented the case for using "emerging technologies" to develop conventional weapons capable of attacking the enemy's rear areas and thus avoiding the resort to nuclear weapons in a future European war. In this article Dr Steven Canby, while recognizing the potential of these technologies, raises serious questions about their operational feasibility. IDR feels that the attempt to strengthen conventional deterrence in Europe is of the utmost importance and that the discussion can only benefit from a hearing of various aspects of the debate. —Ed.

Can emerging technologies offset NATO's inferiority in combat strength in Europe? Proponents say yes — and for only a four percent real increase in defense spending. Proponents argue that we are at the threshold of a new age in warfare — that of electronics. Microelectronics undeniably does offer revolutionary capabilities for sensing and processing data, but the question facing NATO is whether emerging technology can be translated into a significant *military* advantage.

Military history suggests that technological advantage is transitory in nature, readily copied and countered. Truly large payoffs require changes in strategy, doctrine and organization, which may take years to recognize, and still more to be adopted by opponents.

New technologies will change the techniques by which things are done in war, but they will change neither the nature of the activities, such as intelligence gathering, commanding, striking, protecting and moving about, nor the principles by which they are performed, such as surprise, concentrating forces, economy of forces, security, etc.

Nor can the new technologies be expected to benefit the defense over the offense. Contrary to the volumes written on this topic, technology is neutral. Sensing technologies would appear to aid the defender; for the defender is putatively positional and well entrenched, while the attacker must move and expose himself. In this age of firepower dominance, however, the defense too must be based on movement (and elusiveness), if not, the defender will be overwhelmed by fire, enveloped, or defeated in detail by forces with greater initiative. This has been the criticism levelled by reformers against NATO's *implementation* of its otherwise valid concept of forward defense. Most NATO corps now follow more fluid, German-style tactics based on the counter-attack, but NATO still lacks sufficient reserves to execute such a doctrine. The new technologies address the issue of inadequate reserves by attempting to reduce the availability of opposing reserves.

Unfortunately the concept is operationally flawed.[1] Deep attack on runways is potentially most effective when

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▼ A Soviet T-62 tank unit on the march under difficult conditions. The author of this article points out that technologically advanced weapons may be ineffective against enemy armour in close terrain, especially in forests and/or deep snow, where the tanks present ambiguous signatures to IR-imaging sensors.

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Table 1: **Assault Breaker technology demonstration score card**

Mission Function	T-16 flight test										T-22 flight test			
	1	2	3	4	5	6	7	8	(X)	9	1	2	3	4
Target acquisition (radar)				O	O	X	X	X						X
Target position to missile (radar)				O	O	X	X	X						X
Missile launch	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Precision guidance (inertial)	O	X	X	X	O	X	O		X	X	X	X	X	X
Radar track target				O	O	X	X	X						X
Radar acquire and track missile				O	O	X	X	X	TRP	TRP				O
Radar provide guidance update to missile				O	O	X	X	X	TRP	TRP				X
Missile trajectory correction							X	X	TRP	TRP				X
In-flight dispense		⊠	X	X	⊠	X	X	X	X	X	X	X	⊠	⊠
Payload pattern generation		⊠	X	X	⊠	X	X	X	X	X	O	X	O	⊠
Payload descent functioning		O	O	O	X	O				X	O	O	O	⊠
Payload target acquisition and lock-on			X	O	X	O				X				
Target engagement (single)			O	O	X	O				X				
Target engagement (multiple)					O	O				X				
Target engagement (moving)														

Key: Blank — not tested, X — tested successfully, O — tested unsuccessfully, ⊠ — partial test success, (X) — calibration test for fixed site radar to be used in test 9, TRP — tracking radar used for test 9 instead of operational radar.

most aircraft are airborne — as in the surprise attack scenario; thereafter it is little more than nuisance fire. Deep attack on choke points, like river crossings, is classic interdiction. But bridge destruction remains difficult and, in any case, most armies have pre-surveyed additional sites and set aside additional bridging. Nor are follow-on forces queuing behind choke points easily destroyed, as this article will explain.

The emerging technologies are not operationally up to the "deep attack" (75km or more) missions. Electronics has made it possible to sense and hit targets at great distances, while munition payloads can be subdivided into many small but lethal submunitions. However, the guidance technologies are easily spoofed and the munitions themselves readily countered. For the goal at hand — balancing numerical superiority (in teeth units) by technological superiority — the new technologies fail on four counts: the technology trap, incorrect analysis of Soviet operations, operational infeasibility and countermeasures.

The technology trap

In strategic warfare, technology dominates, and much can be mechanically calculated. In conventional warfare, while such calculations are common, they are often spurious. Even one-on-one air-to-air combat calculations have proven invalid, suggesting the importance of intangible factors, such as uncertainty, surprise, training, tactics, adaptability, national character and the like. These factors make war an *art*, not a science.

There is no reason to believe that tactics will not adjust to precision weaponry. Historically, armies have adjusted — or perished. As British strategist Michael Howard reminds us: "I am tempted indeed to declare dogmatically that, whatever doctrine the armed forces are working on now, they have got it wrong. I am also tempted to declare that it does not matter that they have got it wrong. What does matter is their capacity to get it right quickly when the moment arrives."[2]

The proposition that there is a technological solution to offset numerical inferiority has not been proven. In close terrain, as pointedly noted by Bundesgeneral Frans Uhle-Wettler, sophisticated weapons can be disadvantageous. This is most apparent in high mountains, large forests and deep snow, or at night . In these not uncommon circumstances, technologically sophisticated weapons simply cannot cope with an enemy presenting ambiguous signatures.

Sophistication can be tested, too, against analytical models. In the United States, forces have been structured and evaluated in one variation or another on the basis of Lanchester's formula: $K_{red}\,(N_r)^2 \propto K_{blue}\,(N_b)^2$ where quality (K) is a linear parameter and numbers (N) are squared parameters. Among its implications is that, in comparing the British Army of the Rhine and the Soviet Third Shock Army, British technology must be 4 to 9 times better than the Soviet technology to offset Soviet superiority in combat numbers, even though the two are roughly equal in personnel strength.[3]

In the manoeuvre model of war now gaining favour in the United States, however, effectiveness is determined by combattant numbers and overall force quality. Firepower *per se* is not a major determinant. *Surge* firepower remains important but *sustained* firepower does not. The latter simply leads to unnecessary destruction and imposes large logistical demands for resupply and for maintaining lines of communications. Numbers provide command flexibility, while organization and tactics allow small, high-quality lead forces to obtain tactical advantages that can be subsequently exploited, pursued and consolidated by lower-quality follow-on forces.

The nature of the threat matters

Understanding current Soviet operational methods is crucial to evaluating and countering the threat. Soviet operational manoeuvre groups (OMGs) are more than mere high-quality, second-echelon exploitation groups that come into play after a breakthrough.[4] Rather, the OMGs may enable the Pact to skirt the need for concentrating for a breakthrough in the first instance. The new Soviet operational method is a probing approach that seeks natural fissures in the opposing array.

Exploitation reserves are more spatially and laterally distributed than second echelons and "flow " according to developments rather than being echeloned in depth along predetermined axes. Mission assignments and exploitation axes are determined by the course of events. As two US analysts have noted: "...leading echelons...would advance in dispersed formations and on multiple axes.... Once weak sectors were identified, the Soviets would hope quickly to penetrate forward defenses ...cutting off and isolating divisions. In effect, the deep operation seeks to destroy the enemy's defenses with several deep finger-like penetrations that are controlled by a single powerful hand rather than the driving fist of a *frontal* assault."[5]

In the OMG method, breakthrough battles are no longer necessary. The low density of opposing NATO forces is such that there will almost always be gaps to probe, widen and pass through.

Against the OMG method, the putative benefits of "deep attack" disappear, for second echelons are no longer the dangerous element. It is the *extended* first operational echelon that is now critical. The damaging force is the 19 line divisions of the Group of Soviet Forces in Germany (GSFG). The reinforcing formations from the western military districts serve a vital function and may have specific objectives, but they are redundant in numbers, and few are first-line combat units.

Once OMGs "shoot the gap" and enter the NATO rear, targeting by the "deep attack" apparatus is difficult — there will be too much interspersion of forces, and the OMGs will be pulling

Table 2: **Assault Breaker subsystem chances of success**

	%
1. Arrival of bus missile over target area	85
Timely and successful burst and dispense	90
whence, chance of bomblet launch in target area	=77
2. Initiation of "smart" bomblet guidance	90
Initial trajectory within scope of guidance system	80
Timely acquisition of a target	50
Successful line-up or hit	60
Timely fuze initiation	85
whence (from 1 and 2) hit probability	=14
3. F (firepower) or P (personnel) kill	20
whence (from 1, 2 and 3) kill probability	=2.8

(*Source:* R.E. Simpkin, *Antitank*, Brassy's, 1982, p.159)

down the C^3I infrastructure required for attacking deep.[6] There would be little time to deliver many weapons on the pproaching reinforcements, and success is in any case irrelevant if NATO defenses are collapsing.

Technical and operational feasibility are not the same

The central issue in "deep attack" is the importance and ability to interdict (destroy, disrupt and delay) the Soviet second *operational* echelon, originating from the western military districts of the USSR. Attack ranges are out to 300 kilometres.

Interdiction has long been a major task for tactical air forces. They have long sought to locate, strike and destroy opposing ground forces before the ground forces make contact with friendly forces. The problem has been two-fold: poor target acquisition and inadequate munitions.[7] Emerging technologies appear to have removed these constraints.

For targeting, the following is available:

1. Signal sensors (e.g. direction-finders) and airborne motion-detection radar (plus other sensors) with the ability to locate enemy units — which are either transmitting or moving — quickly and accurately.
2. Low-cost digital data-processing systems and display systems permitting real-time processing of operationally significant information to be provided to commanders quickly.
3. Grid systems allowing the integration of information on NATO forces and their locations as well as on Soviet and Pact forces referenced to a common grid.

For munitions, advanced area munitions and better dispensers can in theory reduce sortie requirements by a factor of ten to fifteen.

This is an exciting new potential. But can it be translated into operational capabilities? Weapon development is notorious for failed expectations at great cost. Too many weapons have had high kill probabilities in idealized technical tests and very low kill probabilities in actual combat — often as much as a 10-fold difference.

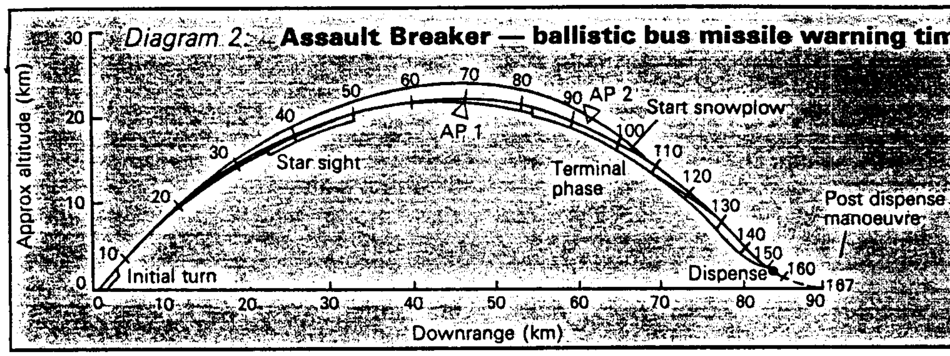
"Deep attack" of mobile ground forces requires the adoption of advances in methods of real-time surveillance, automated targeting and information development. The targeting methods attempt to turn mobile targets into "fixed" targets by assessing past and present location and predictable future locations. This is then coupled to precision-guided delivery systems with terminally guided submunitions. These "deep attack" technologies present a number of major problems, however.

● *Expense:* In a supporting paper for the European Security Study (ESECS), Donald Cotter estimated that only $1,050 million would be needed to *complete* RDT&E for "deep attack" on follow-on forces and $5,850 million in 10-year costs for equipment, missiles and manning.[8] These are not, however, full-cost estimates. When the systems are fielded, high-cost replacement equipment must be available and modifications will become necessary to counter Soviet responses. In addition, effectiveness estimates are wildly optimistic. For example, the inability of sensors to distinguish between tanks and trucks (there are five times more trucks than tanks in a division and still more in the force as a whole) alone gives a 10-fold error. Any estimate is therefore speculative.

● *System breakdowns:* In a hostile environment, complex individual functions from widely different equipment must be stitched together. A failure in one function will bring down the system as a whole. The problem is vividly demonstrated in *Assault Breaker* (see *Table 1*). To date, no demonstration, even in laboratory conditions, has successfully stitched all the functions together, including mid-course correction for deep-ranging missiles. In war, the equipment must cope with dispersion, terrain-

▼ Soviet armour, such as this T-64, would probably not move forward in the rear areas under its own power. According to the author, tanks would be transported by rail and road flatbeds. It would be necessary to hit the transporters as well as the tanks, consuming time and additional munitions.

Diagram 2: Assault Breaker — ballistic bus missile warning time



Events	Time (s)	Guidance
Launch & initial turn	0-8	attitude
Steering aim pt 1	8-52	proportional
Star sight	36-50	attitude
Steering aim pt 2	52-81	proportional
Terminal	81-148	guideline
Dispense prepn	148-151	ballistic
Dispense	151-151.3	ballistic
Post-dispense	151.3-167	max turn

masking and town-masking, signal silence, fast-breaking developments and passive and active countermeasures. Any of these may negate a single function, as may enemy attacks focused on a single equipment function.

● *Equipment and system vulnerability:* Moving-target-indicator radars are line-of-sight sensors. They must be high in the air and relatively close to the FEBA in order to minimize terrain-masking. Such high platforms will be vulnerable to SAMs and fighters. Electronic emissions create another vulnerability. The enemy, too, has detecting and home-on-target weapons. Assuming technology can counter these threats, there remains the vulnerability to ground attack, overt and covert, and electronic security of the computer system.

● *System complexity and rigidity:* Even if science and unconstrained budgets can in principle resolve the above problems, complexity and rigidity are two hazards that cannot be solved technologically. An inherently simple and robust laser-guided artillery system can illustrate these pitfalls. Moving targets are difficult to hit because too much time elapses between the call for fire and the actual impact of the round. Projectile flight typically requires half a minute, to which must be added several minutes for calling in and directing a gun tube. Even on a clear day, a vehicle moving at a modest speed (25km/h) will have moved outside the cone or footprint within which a projectile can be guided on to the target. In cloudy weather, the footprint will be smaller. If the terrain is hilly, the observer-to-target line of sight may be broken.

"Deep attack", as it is now conceived, would be vastly more complex and less adaptable to wartime dynamics than visually confirmed guided artillery. Electronics can sense and process data faster than the unaided observer — its fatal flaws are in interpretation and prediction. Machines can only be preprogrammed. The unexpected renders them useless, even dangerous. Reliance upon them puts a premium on adaptive enemy behaviour.

Remote sensing proceeds from the false premise that "we know the tendencies and pattern of threat units when they are deployed as they would be in a second-echelon formation."[9] This supposition allows correlations to be developed so raw data can be machine-processed (and implicitly interpreted) and used for fire direction, combat formation and intelligence.

According to US Army field manual FM 100-5, three types of correlation can lay out enemy behaviour:

1. Doctrinal templates are models based on enemy tactical doctrine, portraying his frontages, depths, echelon-spacing and force composition, as well as his unit deployments for tactical operations.
2. Situational templates portray how the doctrinal templates will most probably appear when applied to a specific piece of terrain.
3. Event templates serve as models against which enemy activity can be recorded and compared. They indicate the enemy's ability to adopt a particular course of action.[10]

According to the manual, these event templates point to specific areas of interest and can be compared with doctrinal templates to determine the enemy's options and possible course of action. Such thinking and procedures invite the enemy to spoof our programmed machinery. An operationally viable surveillance and target acquisition system must be able to detect and cope with deception and unanticipated behaviour on the part of the enemy. Automated command systems cannot. The development of automated processing has led (or soon will lead) to a situation which provides flexibility only within the realm of the predictable.

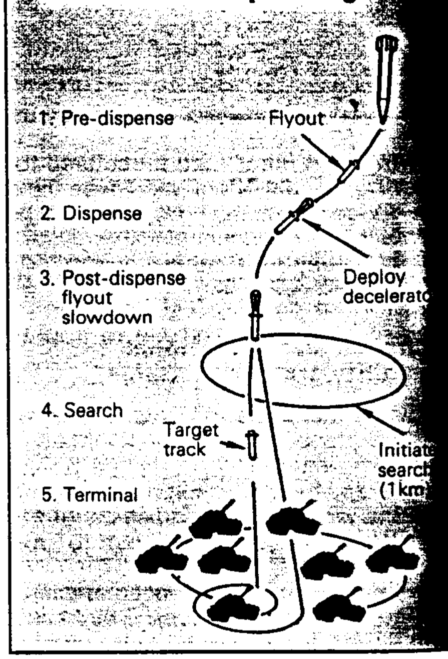
If NATO relies on automatic processors, the Soviets could adapt their behaviour to create inputs to confuse us and, in the extreme case, defeat us. Alternatively, we may deny ourselves the ability to behave adaptively outside the set of the predictable.

Countermeasures and munition limitations

Although munitions and their delivery systems have improved dramatically in the last decade, the projected "smart" munitions will prove ineffective in "deep attack" for several reasons.

● *System mechanics:* Submunitions used in *Assault Breaker* suffer from the phenomenon of linked probabilities. Success is low in the best of circumstances because of the many mechanical tasks that must be accomplished. This sequencing problem is illustrated in the estimate contained in *Table 2* and by *Diagram 1*. The table indicates a hit probability of only 14% and a firepower

Diagram 1: Terminally guided submunition sequencing



or personnel kill probability, given a hit, of 20%, yielding an overall kill probability of 2.8% per submunition.

Kills are correspondingly expensive. The full missile costs $600,000. There are 14 TGSMs (terminally guided submunitions) or 56 *Skeets* for the T-16 *(Patriot)* and 24 TGSMs or 96 *Skeets* for the T-22 *(Lance)*. For the larger T-22, each TGSM kill therefore costs $893,000 (600,000 divided by 24 divided by 0.028), while a *Skeet* kill costs $223,000. *Table 2* is, of course, an estimate. Proponents argue probabilities are higher, which indeed they may be in controlled, but not normal, conditions. But even if they were higher, it would make little difference. There are too many simple countermeasures that can be taken against terminal sensors and small-warhead submunitions like *Skeet*. The TGSM, by contrast is not truly a submunition. It is more like a 120mm mortar bomb.

● *Distance:* On the immediate battlefield, countermeasures are often difficult to orchestrate. When there is no contact with the enemy, there is more time to use the full panoply of countermeasures. In "deep attack", second echelons out to 300km behind the line of contact are to be attacked. With no threat of direct ground attack, vehicles can move administratively and missile-defeating features unsuited for combat can be added. For example, special covers for signature diffusion and added protection would reduce the already low chances of a hit and the lethality of a warhead. Non-combat loading of and minimal crews for armoured vehicles would reduce the possibility of secondary explosions (the condition necessary for a catastrophic kill with *Skeets* and TGSMs). Any damage wrought is likely to be repairable, temporary and of little operational significance. On the immediate battlefield, disablement, however slight, may be fatal, but at 75km or more in the enemy rear, vehicles not catastrophically killed, but merely disabled, can be repaired .

● *Transit:* In "deep attack" the targets are vehicles in transit. At any point in time, some will be at rest in assembly areas where they are not targetable. Reinforcing echelons are vulnerable to attack only during their actual movement, placing a premium on real-time intelligence and response. Real time necessarily imposes pre-determined algorithms — and an inability to escape from the dilemmas posed by behaviour adaptation and spoofing.

● *Time lags:* Although detection could in theory be accomplished in real time, missiles in flight lead to time lags. The lapse of even a few minutes against moving targets means the target is likely to be too far from the projected impact area and beyond the reach of submunitions strewn out from their missile bus. Accuracy for the bus therefore requires a mid-course correction. Otherwise the target's location must be projected or the target presumed to be one among many in a linear array moving across a targeted point. Mid-course correction capability adds to both the expense and the complexity in an already complex weapon system. Moreover, even with data updates, missiles can be defeated by simple detection and warning systems linked to already existing traffic controllers spaced a kilometre apart (*Diagram 2*). Radars can determine points of impact of incoming missiles and the information used to fire sensor-blinding flares/aerosols/chaff from column vehicles and automatic roadside mortars. In addition, since large spaces exist between march elements, speeds can be adjusted to ensure impact areas are void of vehicles.

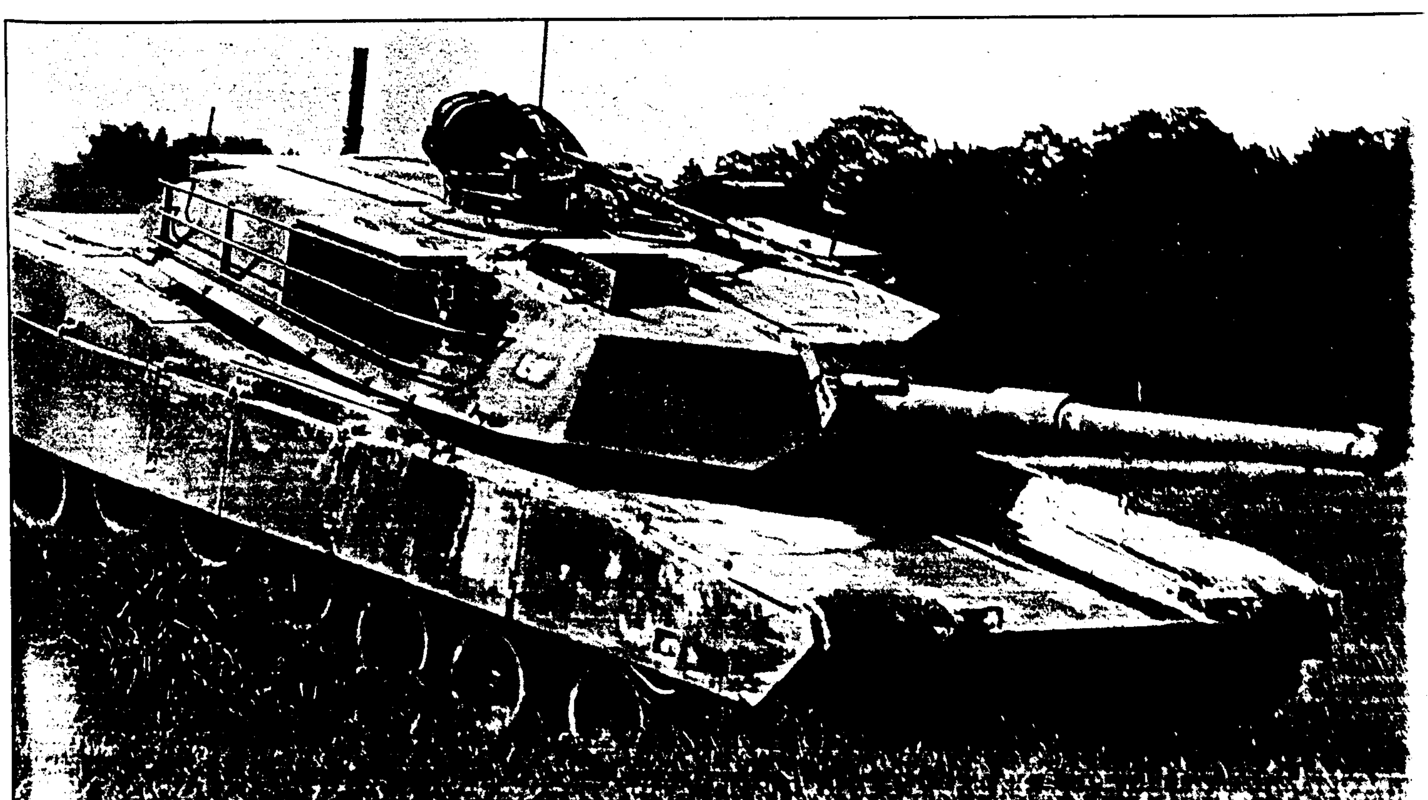
● *Countering sensors and terminal guidance:* Chaff raises the general issue of detection and target classification by long-range sensors as well as the tracking by the terminal sensors in the submunitions themselves. Decoys can draw attention and fire to erroneous targets. Once the missile is en route, decoys can create more "targets" than actually exist, thereby lowering the kill probability of individual submunitions.

False images can also be created to spoof the sensors. Formerly, false images on the battlefield were expensive — they had to deceive visual observations. Now they can be flim-flam. Images can be created by spoofing simple-minded sensors and simulated electronically across a number of senso[r] modes. For example, an MTI radar ca[n] be spoofed by the simple expedient o[f] ten civilians or soldiers jogging or bicy[-] cling in single file with corner-reflector[s] on their caps from town to town an[d] forest to forest, thus appearing as innumerable tank companies. To be sure sophisticated (and expensive) signa[l] processing can detect the spoofing, bu[t] against thousands of apparent tan[k] companies, it is impractical. The attemp[t] would lead to system overload an[d] breakdown.

Decoys can be filtered out by greate[r] sensitivity, signal processing and multi[-] mode cross-referencing. In large mis[-] siles, this is merely a question of highe[r] sensor costs, one cost among many. F[or] submunitions, where the sensor is th[e] dominant cost, the demand for great[er] sensor sensitivity can multiply the co[st] of each missile significantly and means larger submunition diamete[r] and therefore numerically fewer su[b] munitions per bus missile.

Additional complications in termin[al] guidance are inherent in natural clutte[r] weather and masking by terrain. [I] ground warfare where contrasts a[re] low, signatures need only be reduced [to] blend into the natural environme[nt]. Paints and nets are well known f[or] breaking contrasts; advanced varian[ts] can reduce IR and radar signature[s]. Other obvious complications inclu[de] cloud cover and rain for IR-sensi[ng] TGSMs and ground winds for all te[r] minally guided submunitions. Lo[cal] wind strength and direction cannot [be] discerned at great distances. Y[et] because most submunitions are r[e] tarded to slow the rate of fall so that t[he] sensor can take its bearings, wind c[a]

▼ The US M1 *Abrams* MBT has a compartmentalized interior which isolates the crew from the fuel and ammunition. Blow-out panels, which would prevent the loss of the tank in the event of ammunition detonation, can be seen in the rear of the turret roof. Future Soviet tank designs are likely to incorporate such features, thus minimizing the risk of a secondary explosion which is the necessary condition for a catastrophic kill with small shaped-charge warheads. (*Photo:* Ramon Lopez)



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blow descending submunitions out of target footprints.

Besides the masking nature of town and forest, there is a problem with European roads. The better military roads are not the motorways, which would offer clear sensings, but the old tree-lined network still prevalent in the east. Trees diffuse the sensings of in-service IR sensors, and are often more attractive targets in the 8-13 micron band and for millimeter-wave radars than vehicles themselves. Equally significantly, bridges and chokepoints along the old road network are generally sited in or near towns. These towns provide natural protection from detection, terminal guidance and warhead effects. The nature of the road net thus partially defeats one of the putatively attractive features of "deep attack" — the ability to destroy geographically fixed chokepoints, followed by subsequent attack upon "bunched" formations queuing at the obstacle. This requirement remains one of high-tonnage, high-explosive ordnance.

Finally, the only proven and relatively inexpensive sensor, heat-seeking IR, has numerous limitations.[11] For example, the heat from large engines can be dissipated and the engines made to appear small, while small engines can be made undetectable, and decoys, such as roadside fire pots, set up everywhere. Moreover, the primary target in attack on follow-on forces — the tank — generally does not move forward in deep rear areas under its own power. To minimize wear, these vehicles are carried as much as possible on rail and road flatbeds. Other terminal sensors — imaging IR and millimetre-wave radar — are expensive. As well as being susceptible to spoofing by the countermeasures mentioned above, imaging IR can be countered by using plastic boards with embedded wires, millimetre-wave sensors by woven metal nets.

- *Countering small warheads:* Submunition design suffers from a basic trade-off: the greater their number, the greater their overall hit probability — but the smaller their warhead and lethality given a hit. Because the warheads are small, they can be countered in ways not possible with large warheads. Most, necessarily, must hit the target directly; a near miss is not sufficient.

The effects from shaped charges can be countered by dissipating penetration power, reducing internal spalling and preventing secondary detonation and fires. Much is a matter of vehicle design. The M1 tank, for example, has its munitions compartmented (to reduce the chance of ammunition detonation) and blow-out panels (to prevent catastrophic loss if the munitions do detonate). Soviet tank designs could, but have not yet incorporated these safety features, although since the 1973 Yom Kippur War much as been done to reduce spalling and secondary detonation and fire. Even current tanks could incorporate some of these features.

Tanks in the future will undoubtedly incorporate strengthened top armour even if the trade-off is less protection elsewhere. In administrative marches, however, top protection can be strengthened without paying a permanent penalty. For example, blocks of removable ceramic armour and even sacks of children's marbles laid on the decks would be sufficient to defeat small penetrating jets. Against larger submunitions, removable active armour will certainly be able to defeat this type of threat in the future.

Conclusion

Deep attack of follow-on forces falters for several reasons:

a) The underlying premise is false. NATO is outgunned but neither outmanned nor outspent. NATO's problem is organizational and doctrinal; marginal technological advances cannot overcome these self-inflicted wounds.
b) Technology is misfocused on difficult deep attacks rather than on easier and higher-payoff shallow targets (50km from the FEBA).
c) While the individual technologies may work, the many diverse functions have yet to be stitched together and demonstrated in a benign, much less hostile environment.
d) Unless protective measures are devised, the emissions from a fielded system will be large and readily detectable, and hence vulnerable to attack.
e) Cost, using proponents' own claims of effectiveness, are an order of magnitude greater than asserted.
f) Submunitions do not have nuclear equivalence in a deep strike role: the effects are too limited and too readily countered.

Even if the technology worked perfectly and invulnerably, the concept would remain operationally infeasible because it depends on a three-link chain:

— The enemy must concentrate for breakthroughs;
— Command and control must be robust and not subject to spoofing;
— Submunitions must have not only high hit probabilities but also high damage rates given a hit.

All must hold, yet none do.

Even a workable concept does not necessarily enhance deterrence and stability. Should the Soviets conclude the system is effective (i.e. the technologically superior West must know something they do not), the obvious counters are pre-emptive surprise and heretofore concealed countermeasures. In addition, NATO's nuclear threshold might be lowered because its tactical nuclear capabilities would be enhanced (the same sensor infrastructure and missiles could, with some modifications, be used for nuclear weapons). The Soviets could logically conclude that follow-on force attack is a mere Trojan horse for nuclear weapons and NATO has in reality returned to a "trip wire" strategy.

Notes

1. Follow-on forces attack (FOFA) is NATO's concept for fighting the rear battle. AirLand Battle is the new official US doctrine for the tactical use of American tanks and infantry formations; it is in principle *similar* to French, German and Dutch army tactics.

2. Michael Howard, "Military Science in an Age of Peace," *RUSI Quarterly* 119, No. 1, March 1974, p.7.

3. The Soviet advantage varies from 1½ times the logistic lift and quantity of infantry to 2 times the armour and 6 times as many artillery weapons. See Christopher Donnelly, "Soviet Operational Concepts in the 1980s," in *Strengthening Conventional Deterrence in Europe*, Report of the European Security Study (ESECS), The MacMillan Press, 1983, p.135.

4. For a development of the OMG thesis, see Christopher Donnelly, "Soviet Operational Concepts in the 1980s," *Ibid*, pp.105-136. Donnelly's thesis was first openly published as "The Soviet Operational Manoeuvre Group — a new challenge for NATO," *International Defense Review*, 9/1982, pp.1177-1186.

5. Lt Col John G. Hines and Phillip A. Petersen, "The Conventional Offense in Europe", *Military Review*, April 1984, pp.4 and 7.

6. Interspersed OMGs can of course be hit with terminally guided submunitions fired from any number of observer-controlled devices.

7. Brig Gen John E. Ralph, "Tactical Air Systems and the New Technologies," in G. Kemp (ed.), *The Other Arms Race*, D.C. Heath and Company, Washington, 1975, pp.29-31.

8. Donald Cotter, "Potential Future Roles for Conventional and Nuclear Forces in Defense of Western Europe," in *Strengthening Conventional Deterrence in Europe*, report of the European Security Study, The Macmillan Press, 1983, p.243.

9. Gen Donn A. Starry, "Extending the Battlefield," *Military Review*, March 1981, p.43.

10. *FM 100-5: Operations*, Department of the Army, August 1982, pp.6-8.

11. There may also be a fatal limitation. Some question whether the heat from a Soviet T-62 tank is sufficient to activate IR sensors in the 3-5 micron band. The hot-spots on the T-62 and later-model Soviet tanks are well-shielded, probably making them vulnerable only to very expensive IR sensors.